Melvin Kranzberg

HISTORICAL ASPECTS OF TECHNOLOGY ASSESSMENT

August 1969

Program of Policy Studies in Science and Technology
The George Washington University
Washington, D.C.

Occasional Paper No. 4

HISTORICAL ASPECTS OF TECHNOLOGY ASSESSMENT

Melvin Kranzberg

Paper presented at the
Engineering Foundation Research Conference
Andover, New Hampshire, August 1969

Program of Policy Studies in Science and Technology
The George Washington University
Washington, D. C.

Occasional Paper No. 4

ABOUT THE AUTHOR

Melvin Kranzberg is now Professor of History and Director of the Graduate Program in the History of Science and Technology at Case-Western Reserve University. He has served as a Vice-President of the American Association for the Advancement of Science, and Chairman of its Section L (History and Philosophy of Science); is a former Chairman of the Humanistic-Social Division, American Society for Engineering Education; and is currently Chairman of the Historical Advisory Committee, National Aeronautics and Space Administration and Vice-Chairman of the United States National Committee, International Union of the History and Philosophy of Science. Founder of the Society for the History of Technology and editor of its quarterly journal, Technology and Culture, Dr. Kranzberg is editor of the two-volume Technology of Western Civilization (1967) and the author of several books and numerous articles in encyclopedias and scholarly journals on engineering education, French history, and the history of science and technology. In 1967 he was awarded the Leonardo da Vinci Medal of the Society for the History of Technology.

HISTORICAL ASPECTS OF TECHNOLOGY ASSESSMENT

Technology assessment as a limited art is nothing new. Simple assessment is close to the purpose of any innovation, even if only a mere guess that it will work to some good. It goes back to prehistory. We can imagine some forebear of _homo sapiens_ picking up a stone to kill small game or to beat a neighbor--or his wife--over the head. He had glimpsed the purpose in advance. He immediately confirmed the efficacy of the weapon, no doubt with grunts of delight.

Every new tool, machine, process, technique, design, or product is judged in the light of its efficiency in meeting some need. Technology assessment still tries to answer questions about efficiency, cost, and function related to purpose. These questions run to how to make work easier or life more pleasant, how to make money, how to kill or destroy more effectively, and in general how to achieve specific goals the innovators seek. For most of history, technology assessment has been narrow and immediate, but within these limits perhaps effective. More remote and broader effects were ignored.

The pyramids, for all we know even today, preserved and sustained the pharaohs' _ka's_, or spirits, in the afterlife. From the standpoint of the pharaohs--and they were the only people whose assessments counted then--the pyramids were a worthy allocation of resources, admirably fulfilling the special requirements for the afterlife of the god-kings. From the standpoint of the millions of workers whose labor built these great monuments and of the inhabitants of Egypt as a whole, the pyramids were an unmitigated disaster. Still, the pyramids satisfied first-order assessment in the light of Egyptian learning and social structure, which placed the pharaoh at the top of the pyramid, figuratively speading.

Throughout history most other first-order requirements have been economic or military in nature, conceived in the narrowest possible fashion. But second-order effects--effects on the entire economy, social effects beyond the economic, the socio-economic aftermaths of war affecting both victor and vanquished--these were rarely, if ever, considered. Second-order and more remote effects occurred, of course, but their prediction was diffuse and unlikely to be convincing. In that connection I recall a cartoon which appeared many years ago in the late Collier's magazine. A caveman emerging from his cave with a bow-and-arrow remarked to his companion, "This new little invention of mine will make war so horrible that men will never make war anymore."

Only when random invention began giving way to systematic innovation could technology assessment look much beyond first-order effects. Yet failure to assess the far-reaching effects of technology did not, as I have noted, keep them from occurring. Vast improvements in man's living conditions, his conquest of the environment, and the uplifting of social and educational standards were wrought by technological advances in agriculture, construction, transport, and communications--even though for the most part innovations in those fields were made by men who considered only limited first-order effects.

By now we have awakened to the fact that technology has social and human effects which we historians can clearly detect by our 20-20 hindsight. Today we claim--or some of us claim--that these effects are calculable in advance. The historical developments which have brought about this change I shall discuss under the headings of (1) the broadening through the centuries of the social context for technological change and assessment, (2) the growing need since the Industrial Revolution for assessment, (3) the recent deepening awareness of the impacts of technology, (4) the development of social and communal responsibility for technology, and (5) the current growth in the assessment capability.

Broadening of the Social Context for Technological Change and Assessment

The example of the pyramids showed how technology assessment once was concerned with but a single individual, the god-king. In classical antiquity, and indeed through much of history, the range of assessment extended only to the benefits for a small, elite group. This limited the impetus for technical innovation. The Hellenistic scientists, for example, knew about the power of falling water, the force of air pressure, and the energy of expanding steam. They were familiar with the principles of force pumps, water wheels, windmills, rotary grinders, and even the reaction steam turbine. But instead of using this knowledge and these mechanical appliances to perform work, they made toys.

Hero of Alexandria, who lived in the first century A.D., described 78 machines in his treatise of Pneumatics. There were siphons for producing the illusion of turning water into wine. One contrivance lit fires in hollow altars; the expansion of the air exerted pressure through concealed pipes forcing libations of liquids onto the flame. Another air-expansion device within the altar opened the doors of the temple and later, as the fire died, closed them automatically. Hero is even said to have devised the first automatic vending machine. It sold holy water, an automatic vending market which has so far eluded the Mafia in our country.

Hero and the other Hellenistic scientists failed to apply scientific knowledge and discoveries to control the environment by reason of social, not intellectual, deficiencies. They considered only the welfare of a small number of individuals rather than the entire population. The majority of the people were workers, the lowest elements of society and, in most cases, slaves. There was little need to improve technical devices to save cheap slave labor.

Medieval society, still elitist in nature and contemptuous of manual labor, dropped the institution of slavery, and despite the popular myth to the contrary, the rising classes of artisans and merchants were receptive to technological change. The guilds of canny craftsmen were quite aware that if they failed to adopt an innovation in production, other artisans would, and markets in the next city might be lost.

When the spinning wheel first appeared in Europe toward the end of the 13th century, it must have caused unemployment. Yet the first mention of the spinning wheel in a guild regulation of about 1280 merely prohibited the use of wheel-spun thread in the warp (as distinct from the weft), presumably because it was not yet as strong as that produced by hand. The object, then, seems to have been to protect the quality of the cloth, not to rule out technical improvements.

On close inspection, we find very little guild opposition to industrial changes before the 16th century. When opposition appeared, it was because the pace of technological change was quickening, and a new industrial system was beginning to appear. The guild structure itself was slipping, fighting in vain for its very existence. As a flourishing part of medieval society, the guilds were strong enough to accept technological change; only when the structure lost touch with the new economic order did the attempt to block change begin.

The medieval guild cannot rightly be compared with the modern labor union. Certainly, however, their limited view of technology assessment in the face of new modes of production, once their very being was threatened, seems fairly analogous. Featherbedding practices and building codes represent indirect forms of technology assessment considering only the welfare of the small segment of the population actually engaged in running trains or building houses, not the welfare of those using them, and certainly not the entire community.

Despite the later guild opposition, the onset of industrialization turned out to be irresistible. Yet, if there was anything that could be called technology assessment, it was limited to first-order economic effects, namely, the profit of individual businessmen. Their sponsorship of technological innovation on behalf of their own self-interest was largely unchallenged because of the concomitant development of new concepts of private property based on natural rights and, somewhat later, on the doctrines of laissez-faire.

When opposition to industrialization began to appear at the beginning of the 19th century, it was confined to small, special-interest groups whose selfish concerns seem almost trivial today. In England some members of the country gentry objected to the spoliation of the countryside. They had in mind their own hunting rights hedged by railroads puffing their way across the landscape. They also resented the rise to economic, and eventually to political, power of the self-made men representing the burgeoning industries.

The Luddite protest, more dramatic, has been interpreted by many as the first indication of worker opposition to the onset of industrialization. We know now that the Luddites destroyed their machines, not so much because they opposed the mechanization of their work, but as a means of venting their anger and frustration at the practices of their employers. Yet the Luddites have become symbolic of opposition to machines. Certainly their protest was a harbinger of things to come insofar as technology assessment is concerned. For the first time, there was a real challenge to the notion that only the profits of the factory owner were to be considered in adjudging the worth of technological change.

Although the factory legislation of the early 19th century was largely ineffectual and did little to stop the gross exploitation of workers, it marked an extension of the concept of technology assessment to include the workers, their health, and their economic welfare. This legislation also brought a new factor into technology assessment--the government. Prevailing laissez-faire doctrines aside, the government intervened to mitigate some of the worst social consequences of unfettered industrialization. It was a sign of things to come.

The man chiefly responsible for broadening the social context of technology assessment was Karl Marx. He made plain one great truth: Technology has social and cultural ramifications far beyond the first-order effects to which attention had hitherto been directed. This view took the central position in the all-embracing Marxian theory of history--a theory which, however unfortunate in politics, has deeply influenced the study of society.

What is more, Marx avoided the confusion between technology itself and the social system which it had so profoundly affected. Marx's strictures were not against technological change. He called for greater progress in technology and sought to stimulate technical advance. Indeed, he devoted many pages of praise to the industrial bourgeoisie in a work dedicated to its overthrow, called Das Kapital. His effort concentrated not on mitigating the effects of technology but on rearranging, by revolution, a socio-economic system which would enable the benefits of technology to be spread among the masses rather than confined to the profit of a few.

Aside from a few English gentry and some spokesmen for the Romantic movement during the mid-19th century, not many worried about the inroads of industrialization on the natural landscape. In America the concern about the physical environment was largely based not on aesthetic considerations, but on the question of rational exploitation of natural resources. John Wesley Powell, who became director of the U.S. Geological Survey in the last quarter of the 19th century, conducted an irrigation survey to identify, locate, and conserve the fast-disappearing water resources of the arid western lands. Powell's attempts at scientific conservation were at best only partially successful. John Muir,who sought to preserve forest lands from sale to commercial interests,also met with only partial success. Yet environmental considerations were introduced to technology assessment, a factor which was to become of great importance only by the mid-20th century. It was an extension that would bring technology assessment in time to consider the protection of posterity itself, just as the societal context of technological change had already become broadened to include all segments of society.

The Growing Need for Technology Assessment

The Industrial Revolution was a tremendous enlargement in the scale of technology. Not surprisingly, the new dimensions produced enlarged impacts of society and humanity. For one thing, there were simply more people around. For another, all the extra people were more intimately affected by technology due mainly to crowding and the increasing economic interdependence of mankind. Through most human history, the vast majority of mankind had lived in rural areas, and their major occupation had been concerned with agriculture. The Industrial Revolution changed all that. Production, once centered in the hearth and home, now was carried on in factories located in cities. The self-sufficiency of farming life gave way to the close-linked interdependence of individuals in the modern metropolis. Now other groups in society besides the elite, the artisans, the merchants, and the capitalists clamored for some of the benefits of advancing technology. The factory workers' first-order assessment of their own benefit frequently clashed with those of their employers. And beyond them all was society as a whole, whose interests might suffer even if workers and employers could compromise on their mutual benefit.

The need for technology assessment was also heightened by the acceleration of social change, which was itself a corollary of speedier technological change. Anthropologists tell us that among the most deep-seated of cultural habits are courtship patterns. After remaining static for centuries, courtship patterns have been revolutionized several times within our own century. Henry Ford's automobile not only brought the farmer to the city; it also changed the wooing spot from the front parlor to the rumble seat. Just where the locale d'amour is now, I am much too professorially dignified to find out, though I occasionally stumble over people billing and cooing their way to the bachelor's degree in the bushes of an urban campus. Despite this throwback to the primitive setting, I am always sure--without necessarily looking--that the festivities are being conducted with due regard for second-order assessment of the biological technologies. My own thoughts about the abundant resources of human love, however, are turning increasingly toward conservation.

The United States, too, is rapidly advancing into middle age. Natural resources, like love, once seemed so abundant that little thought had to be given to conservation. As we grew up, advances of scientific technology in new materials and substitutes tended to avoid questions of exhaustion, but we cannot continue to ignore them. Conservation has now become at least a requirement of second-order technological assessment. As one writer has put it, "We have not run out of fresh water in this country; we have simply run out of streams to pollute."

Not only the scale but the cumulative nature of our technical applications is endangering us. The emissions of a few thousand automobiles posed no great threat to the salubrity of the air. Millions of automobiles do pose a serious threat. And DDT provides another example.

Thirty years ago, DDT was hailed as a miraculous insect killer. During World War II, it kept our soldiery free of the lice and vermin infestations which had produced more casualties in World War I than actual combat. In large-scale public health programs throughout the world following World War II, DDT succeeded in wiping out one of mankind's greatest scourges, the malarial-carrying insects. Similarly, when sprayed on crops, it enormously increased agricultural productivity. It is not surprising that the developer of DDT was awarded the Nobel Prize for Medicine. Yet today DDT is regarded as a potential threat to mankind. Through a process of biological magnification in the food chain, slight traces of DDT build up as poisonous doses in fish and birds, and eventually in man himself. In this way a one-time boon to man has become at best a mixed blessing. The magnitude, accumulation, and human impact of technological change, together with technologically produced social change, have made pressing the need for technological assessment in all human, environmental, and social aspects.

The Deepening Perception of the Impact of Technology

The awareness that technology can sometimes have harmful effects is not new. In classical antiquity, Xenophon expressed a prevailing social attitude when he said in Book IV of the *Oeconomicus*, "What are called the mechanical arts carry a social stigma and are rightly dishonored in our cities. For these arts damage the bodies of those who work at them or who act as overseers by compelling them to a sedentary life and to an indoor life, and in some cases to spend the whole day by the fire. This physical degeneration results also in deterioration of the soul."

Similarly, John Ruskin in the 19th century looked back to an older, medieval England, "ye merrie olde Englande" of cakes and ale and morris-dancing on the green. Unfortunately, ye merrie olde Englande was not "merrie" for the vast majority of its inhabitants who lived in fear, poverty, superstition, and filth. Jacques Barzun of Columbia University is a contemporary example of the aristocratic, nostalgic, romantic discovery of the horrors of technology. His book, *Science: The Glorious Entertainment*, is a compendium of common complaints about modern living: useless machinery, ugly architecture, tasteless bread, planned obsolescence, offensive advertising, zip codes, automatic telephone dialing, and the like. The destruction of rural life, the mass exploitation of the poor, cancerous growth of cities, and the uglification of the world through noise, fear, and filth--these Barzun and his fellow "bleeding-heart humanists" laid at the door of technology and science.

What strikes me about these criticisms is not that they are based on a perceptive assessment of the social implications of technology but rather upon a false view of an idyllic past. In these days of urban sprawl and the ravenous bulldozer, it is not surprising that many men look back with fondness to small-town life and nostalgically believe that in many ways the past, which they usually identify as anytime before 1914, was much superior to the present. I am not at all certain that American small-town life was really idyllic, and I invoke Sherwood Anderson, Theodore Dreiser, Sinclair Lewis, John O'Hara, the Lynds, and Tennessee Williams as my witnesses. If the small-town "good old days" were really so good, how are we to account for the fact that so many Americans fled the small town? Perhaps the pronvincial, parochial, censorial, gossipy, uncultivated world of Peyton Place does not correspond so much to human desires as the challenge and excitement of the big city with all its traffic snarls, television serials, and perpetual crises. The fact is that the migratory trend is from the countryside to the city, not the other way. A decade from now more than 90% of all Americans, it is estimated, will be living in urban areas.

Not all the broad-scale attacks upon contemporary technological society arise from romantic longings for a non-existent past. The modern novel, the contemporary drama, and today's poetry have as an insistent theme that man has become the victim of a dehumanizing technology. This literature of anti-technology employs the metaphors of Frankenstein's monster, robots from R.U.R., and the regimented citizens of Brave New World and 1984. The "bleeding-heart humanists" who misquote these works seem confident that their technological target material cannot read the books. What the original books and plays said is not that technology is at fault, but its human abuse. What's worse is the view of man put forth by the non-critics of these works; they claim that man is by nature so abusive, so evil an animal that he cannot be trusted with technology. Well, that is some kind of assessment.

More serious critics base their assessments on better philosophical and literary grounds. Though willing to admit that technology has "raised the ceiling of human achievement," Lewis Mumford claims that modern technology--he calls it "technics"--has become authoritarian and is "transferring the attributes of life to the machine and the mechanical collective." Jacques Ellul has a similar apocalyptic view, feeling that technology has become the end of human life. Fusing ideas borrowed from both Freud and Marx, Herbert Marcuse attacks industrial civilization on the grounds that it has made man "one-dimensional." Even admitting that more men may be happier today than ever before, their happiness, he claims, is "a state of anaesthesia." Though technology has done away with scarcities, it forces men, says Marcuse, to "exhausting, stupefying, inhuman slavery," alienating the workers from each other, from their products, and from work itself. Mass society provides bread, circuses, and technology. Material plenty yields no spiritual gratification and leads to social oppression. Marcuse holds these principles to be self-evident in both capitalist and communist societies. They characterize industrial civilization no matter what the sociopolitical arrangements may be.

Marcuse offers little in the way of solutions. All efforts at reform are impotent, he claims. Free speech and electoral activity are superficial devices for adjusting people to the _status quo_. Revolution is all but impossible. Marcuse can only offer strident opposition to the society either by withdrawal or by confrontation which will shock society into changing. Here is technology assessment of the most sweeping character.

While such wholesale indictments may stimulate nihilistic revolutionary movements, they really tell us very little about what can be done to guide and direct technological innovation along socially beneficial lines. Twentieth-century man will never willingly divorce himself from technology nor even consent to a moratorium on further advances. The sentiments uttered by Marcuse and his youthful adherents might ultimately succeed in bringing about major transformations in the softer supporting systems--legal, educational, governmental, economic, and the like. They are ineffectual as to technology because of their intellectual murkiness about changes in the dynamics of technology itself. Still, they render two cheers, heavily, for some kind of technology assessment. Mumford, Ellul, and Marcuse deserve "A" for choice of topic, and "D" for effort. They have nevertheless raised a right question: Do technological innovations really help all mankind or are they only for the benefit of a few? The people who really made the public understand this question were, of course, neither philosophers nor historians.

Rachel Carson, in her book, Silent Spring, first attracted wide attention to the harmful effect of pesticides that persist and accumulate in the environment. Her picture of a silent spring where the birds no longer sing in a despoiled natural environment made her book into a bestseller. It instigated Congressional investigations and scientific studies, and awakened the public. Ralph Nader's book, Unsafe at Any Speed, attracted attention to the problems of automobile safety by showing how Detroit, in its efforts to attract sales through high styling and attempts to economize for competitive reasons, frequently gave second place to safety considerations. His work, too, brought about Congressional investigations and awakened the public to dangers inherent in a technology where motivations for private profit ignored public welfare.

Both books resulted in legislative action, indirectly and directly. Federal legislation for the installation of safety devices in automobiles and an increasing amount of state legislation on DDT bear witness to the effectiveness of these popular writers, the one a first-class scientist, the other a well-educated lawyer, in bringing about meaningful technology assessment. Thanks to Carson and Nader more perhaps than anybody else, awareness of the need for technology assessment has been deepened in the United States.

Development of Social and Communal Responsibility

About a century ago society began to recognize that rampant individualism armed with natural rights doctrine concerned with interests in property did not necessarily result in the social welfare of all. The reason that Adam Smith's "invisible hand" was unseen was because it simply wasn't there. The sum of individual self-interests did not result in the wealth of nations. If society were to insure security and justice for all its members, it was evident that the government must become a very visible hand in guiding, controlling, and limiting individual rights in the interests of the community at large. This was particularly the case when, through the enlargement of the franchise and the growing democratization of society in both Europe and America during the 19th century, larger numbers of the population could make their voices heard in government and could demand public attention to their needs. Viewed in this light, technology assessment is simply another step in governmental intervention for the common good. Let us look back at some precedents of government direction of technology in America.

In 1824, casualties from boiler explosions on steamboats, particularly an explosion on the Aetna in New York Harbor, which killed 13 and caused many injuries, made Congress take notice. A resolution was introduced in the House of Representatives in May 1824 calling for an inquiry into the expediency of enacting legislation barring the issuance of a certificate of navigation to any boat operating at high steam pressures. This bill did not pass, but the continuance of such explosions during the next few years created a powerful public demand that something be done.

Since nobody knew the exact reason for the boiler explosions, the first order of business was to investigate the cause. In 1830, finally, the government made its first research grant of a technological nature, employing the Franklin Institute of Philadelphia to investigate the cause of boiler explosions. Not until 1836 did the Institute present its full report and make detailed recommendations for regulatory legislation. It was to take another two years before a law was passed, and that so watered down that the suggested inspection criteria and standards for steamboat engineers were eliminated. Boiler explosions thereupon continued with increasing losses of life. In 1852, at last, a law with teeth in it was passed, with a regulatory agency to enforce it.

Other problems involving technology were taken up in the same piecemeal fashion: first canal building, then railroad building, and, when manned flight was young, the National Advisory Committee for Aeronautics was established. These were followed by the Atomic Energy Commission, the Office of Desalination in the Department of the Interior, and investigating committees on automobile safety, insecticides, and the like. All these agencies were involved in technological goals and purposes, but they confined themselves for the most part to specific problems. Broader assessment has come very slowly.

An attempt to institutionalize and regularize the giving of scientific advice to the government, the prelude to technology assessment, occurred quite early. The National Academy of Sciences was established in 1863, and on the infrequent occasions when it was asked for advice, the advisory approach was used primarily for individual projects or problems. But what about the problems arising from the combined impact of many different systems? And what about social systems in relation to science and technology

Powell's attempt to achieve a rational scientific basis for a conservation program in the western lands was, indeed, a broad-scale approach to the combined impact of several different technological systems and many special interests. However, perhaps the most systematic attempt of the government to confront the consequences of scientific and technological developments was to be found during the New Deal in the Temporary National

Economic Committee (TNEC). The TNEC hearings, begun in December 1938 and lasting 18 months, were triggered by the economic recession of 1937, and they resulted in the most thorough investigation of technology and its implications in our history. The committee sat for 775 hours of testimony, listened to 55 witnesses, and published its hearings; its exhibits, reports, and transcripts fill two good-sized shelves. The problem under closest scrunity was of course technological unemployment. Nevertheless, the research potential of industry and the effects of the patent system in encouraging technological advance were considered on issues of corporate monopoly, which was at the whipping post. Representatives of special interest groups-largely labor and management-made their cases. Few witnesses represented the public interest. Little consideration was given to second-order effects of technological advance, although much was implicit in the economic analyses presented to the committee. The President's Commission on Technology, Automation, and Economic Progress in the 1960's made a similar large-scale effort to consider the effect of technological change on American society. Yet it, like the TNEC, was a "one-shot deal;" it did not represent a continuing effort in technology assessment.

Parallel with these short-lived efforts to view the larger social consequences of technological change was an extension in the concept of the public whose welfare the government sought to serve. Pesticides again provide the example. The first federal law dealing specifically with pesticides was the Federal Insecticide and Fungicide Act of 1910, which sought to protect the pesticide user--the farmer--from being bilked by manufacturers who were selling him inferior products. It took almost three decades before the protection of the federal government was extended to the general consumer, the public which ate the food products grown with the aid of pesticides; this was the 1938 Food, Drug, and Cosmetic Act which was designed to protect the consumer from harmful chemical residues in his food. Rachel Carson gave a new dimension to the concept of the consumer of pesticides by showing their effects on wildlife.

As of now, therefore, several federal agencies are concerned with protecting the public in regard to pesticides: the Department of Agriculture protects the farming public which uses pesticides in growing crops; HEW protects the consuming public which eats food products grown with pesticides; and the Department of Interior is concerned with protection of wildlife and, in a sense, with the protection of future generations of Americans, by attempting to preserve the ecological balance for posterity. The pesticide story thus manifests the development of governmental responsibility for the social impact of technology; it reflects a broadening of our national goals from a preoccupation with narrow economic elements to the physical health of the consumer and, ultimately, the general social welfare of the people and their physical environment. Or, looking at it in another way, we find that our government of the United States must concern itself with the welfare of all the inhabitants of our land--birds, bees, animals, and fishes, as well as that peculiar animal, man.

Increasing Assessment Capabilities

Given the historical opportunity, need, concern, and precedents, have we developed the know-how for meaningful technology assessment? I need not review in any detail the very recent history of man's growing ability to collect and manipulate data. Both the hardware and the software

are becoming increasingly accurate and sophisticated, enabling us to deal with dynamic variables in complex situations. Along with these are fundamental developments in mathematics, statistics, and general systems theory. Attendants at an Engineering Foundation Research Conference scarcely need to be reminded of the great strides made in our ability to store and retrieve information.

Many scientists and engineers tend to be skeptical of these techniques when applied to problems involving human and social factors. Though such skepticism may have been warranted only a decade or so ago, it can no longer be maintained. It is now possible to produce dynamic models of systems involving complex human and social variables, and our skill is growing. Systems and operations researchers are increasingly competent to provide probabilistic data regarding the impact of scientific and technological decisions on social trends and changes. Though the information may not be so "hard" as that obtained in the physical sciences, it represents a giant leap forward--to use a now famous phrase--in man's ability to quantify social behavior and to develop social indicators. It is precisely in this area of second-and-higher-order effects that our assessment capabilities have progressed.

Yet our growing knowledge and expertise in the behavioral sciences would be of little value in technology assessment if not accompanied by the growth in our scientific and technological capabilities. These give us technological alternatives which alone can make technological assessment reasonable and meaningful.

Let me explain. In societies where the level of science and technology is low, they must make use of any and every technological advance which they can afford in order to subsist, even if the applications have harmful side-effects. For example, while Sweden and the United States can afford to ban DDT, countries like India cannot afford to do so. It would not be economically feasible for India to change to an insecticide less persistent than DDT which would require spraying every few weeks instead of twice a year. Yet India must have the insecticidal benefits from DDT despite its harmful effects. Its use there has cut down the incidence of malaria from 100 million cases a year to only 15,000 cases, and the death rate from 750,000 to 1,500 a year. In more advanced industrial countries with higher standards of health, malaria presents no such problems.

Furthermore, our higher technological level enables us to use technological alternatives at a slightly higher cost, let us say. The search goes on for other methods of pest control--chemical, mechanical, and biological--and it is quite likely to be successful. Only nations possessing this kind of potential can offer technological alternatives allowing response to unfavorable technology assessments.

What I am really saying is that one major result of the technological revolution of our time is to increase man's choices and options. Our high level of scientific knowledge and technological performance gives us the ability to pick and choose among different ways of accomplishing our social goals. This possibility of choice makes technology assessment both meaningful and possible.

Conclusion

One of the clichés of our time is the well-known statement that "there is nothing so powerful as an idea whose time has come." This is powerful rhetoric but bad history. Anybody can name several ideas whose time is long past but which exhibited little power. Notable among these are the concepts of world peace and human brotherhood. They have been around for some 2000 years, accepted in theory but never in practice.

Technology assessment strikes me as an idea whose time has come, but I think it also has the power. It, too, is a matter of the human heart, but it also has some powerful hardware and interests behind it.

In this brief review of the historical aspects of technology assessment, I have endeavored to outline the development of the factors suggesting that the time has come for technology assessment. Technological changes now have a broader and accelerating social impact. The need exists; the awareness of the need exists; precedents for its application are manifold; and we are developing the capabilities to apply it effectively.

What really counts--and the examples of world peace and human brotherhood plague us on the point--is our willingness to apply it in practice.